PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04Q 7/30

A2

(11) International Publication Number: WO 98/57509

(43) International Publication Date: 17 December 1998 (17.12.98)

(21) International Application Number: PCT/FI98/00497

(22) International Filing Date: 9 June 1998 (09.06.98)

(30) Priority Data:
972461 10 June 1997 (10.06.97) FI

(71) Applicant *(for all designated States except US)*: NOKIA TELECOMMUNICATIONS OY [FI/FI]; Keilalahdentie 4, FIN–02150 Espoo (FI).

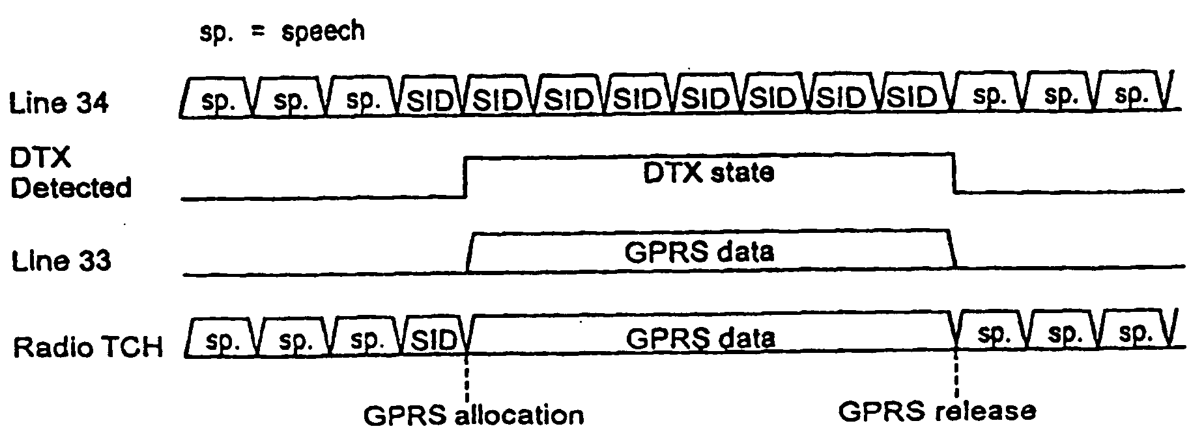
(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: MOSLEMIE, Abbas [FI/FI]; Pajalahdentie 4 A 9, FIN–00200 Helsinki (FI). RAHKONEN, Pekka [FI/FI]; Ulvilantie 23 E 57, FIN–00350 Helsinki (FI).

(74) Agent: KOLSTER OY AB; Iso Roobertinkatu 23, P.O. Box 148, FIN–00121 Helsinki (FI).

(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: METHOD FOR INCREASING DATA TRANSMISSION CAPACITY IN A RADIO NETWORK



(57) Abstract

The present invention relates generally to radio networks particularly to methods for increasing data transmission capacity in a radio network. In the invention, the capacity of a radio network is increased by utilising any pauses or moments when less transmission capacity is needed in a stream of information (voice or data signal) of a circuit–switched call, i.e. moments when a call is in a discontinuous transmission state (DTX), for transmitting packet data from a base station on the same downlink traffic channel (Radio TCH). When a circuit–switched call switches to a DTX state (transmission of information is interrupted), data (GPRS DATA) of a packet–mode call (calls) is transmitted on the traffic channel allocated for the circuit–switched call, until the discontinuous transmission state ends. A traffic channel can be allocated for packet data transmission (calls) separately in connection with each DTX state, and typically to different mobile stations than the one to which the traffic channel is allocated for circuit–switched transmission. The transmission capacity can thus be allocated effectively to network users that need capacity. The mobile stations may belong to different systems, such as a packet data radio network and a circuit–switched radio network.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PC

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

METHOD FOR INCREASING DATA TRANSMISSION CAPACITY IN A RADIO NETWORK

FIELD OF THE INVENTION

The invention relates generally to radio networks and particularly to methods for increasing data transmission capacity in a radio network.

BACKGROUND OF THE INVENTION

The major factor limiting the capacity of a radio system is the limited frequency spectrum available. The capacity of a radio system thus depends on how effectively the radio frequencies assigned to the system can be utilised. In cellular radio systems, more effective use of radio frequencies is based on reuse of frequencies: one and the same frequency is used in a plural number of locations sufficiently far apart, which greatly increases the capacity of the system. However, it also adds to the complexity of the network and the mobile stations, since the mobile stations must be able to select a base station from a plural number of potential base stations. For example, if one and the same frequency is reused in every ninth cell, spectrum allocation of N frequencies allows simultaneous use of N/9 carrier frequencies in any given cell. A reduction in the cell size or the distance between cells with the same frequency increases the capacity, but it also increases co-channel interference. Because of this, determining of a frequency reuse coefficient is often a compromise between co-channel interference and traffic capacity.

Since a frequency spectrum allocated to a cellular radio network is fixed and the number of subscribers is growing quickly, efficient use of the frequency spectrum allocated is vital to every network operator. Different attributes increasing the traffic capacity in a cellular network thus help the operators particularly in densely populated urban areas. Alternatives for developing radio networks to high-capacity radio networks are mainly the following: increase in the number of channels, division of cells (small cells), microcell networks, multilayer networks, underlay-overlay networks, and other capacity-increasing solutions, such as half rate channels, frequency hopping, and power control. In the following we shall study the alternatives in greater detail.

The simplest way of increasing capacity is to add the number of channels. Since a frequency spectrum of a cellular network allocated to a network operator is very limited, the method will not alleviate the problem of capacity. The division of cells involves planning problems, and requires

investments in base station sites and data connections. The division of cells is a good way of alleviating the problem of capacity up to a point. Unfortunately, the requirements of capacity are so high in urban areas that the method does not solve the problem in the long run. The division of cells thus offers only temporary alleviation. The same problems are also encountered in microcell networks.

An underlay-overlay network comprises two (or more) separate layers of cells: one, e.g. a macrocell layer, provides total coverage, and the other, e.g. a microcell layer, provides capacity. The 'coverage layer' uses a normal frequency reuse pattern and cell range to provide seamless total coverage. The 'capacity layer' uses a very dense frequency reuse pattern and a shorter cell range to achieve a high capacity on some channels. In an underlay-overlay network, handover between network levels is critical in respect of the capacity gained. Yet another known and effective way of increasing the capacity of a cellular network is cells comprising frequencies with different reuse coefficients. At frequencies with a greater reuse coefficient, good coverage is achieved, and at frequencies with a smaller reuse coefficient, additional capacity is achieved in the middle of the cells.

In digital mobile systems, voice transmission is totally digital. A band width required by a radio connection on the radio path can then be reduced by using voice coding in voice transmission, whereby a lower transmission rate, e.g. 16 or 8 kbit/s, is achieved than with the 64 kbit/s rate typically used in telephone networks. Both a mobile station and a mobile network must naturally have a voice codec for coding voice. On the network side, voice coding functions can be located in several alternative positions, e.g. at a base station or in connection with a mobile switching centre. In each voice-containing call received at or made from a mobile station, a voice codec is connected to the voice connection on the network side, the voice codec decoding a voice signal received from the mobile station (uplink) and encoding a voice signal transmitted to the mobile station (downlink).

In some digital mobile systems, voice transmission is also associated with Discontinuous Transmission DTX. It aims at improving the efficiency of the system by reducing the interference level by inhibiting transmission of a radio signal when it is not necessary for the information. In addition, the DTX reduces the power consumption of a mobile station, which is important in battery-operated portable terminal equipments. A DTX state is

usually alternative to a normal state, and the choice between these two is made in the mobile network specifically for each call. In the DTX state, voice is coded normally at e.g. 13 kbit/s when the user is speaking, and during any pauses in the voice a much lower bit rate, e.g. about 500 kbit/s, is used. The lower bit rate is used for coding information from background noise on the transmission side. For example, in the Pan-European digital mobile system GSM, a transmitter (mobile station or base station) usually sends one burst of traffic per one TDMA frame (i.e. 96 bursts/480 ms), until a voice codec detects a quiet period in the voice signal. The transmitter then sends only 12 bursts/480 ms. On the reception side, the background noise is regenerated to the receiving station - which is why the noise is called comfort noise - so that the subscriber will not think that the connection has been lost during the pauses in the transmission. The function monitoring at the transmitting end whether there is any voice activity is called Voice Activity Detection VAD. A decision whether a signal contains voice or background noise is typically based on a threshold value and on a comparison of the signal energies measured.

Comfort noise is generated because experience has shown that the receiving subscriber will be greatly disturbed if the background noise behind the voice is abruptly stopped. This would happen regularly in discontinuous transmission. One way of avoiding the above disturbance is to generate artificial noise when no signal is received. The attributes of the noise are updated regularly and transmitted to the receiving end by a voice encoder located at the transmitting end.

Discontinuous transmission can also be applied in data transmission if the rate or amount of data varies during the call. In multi-channel high-speed circuit-switched data transmission (HSCSD) two or more parallel traffic channels (subchannels) are used for a single high-speed data connection on the radio path. A situation may occur in which the speed of information payload data is much smaller than the maximum speed of data allocated for the connection, and half-empty or empty data frames must be sent on the traffic channels. In the discontinuous data transmission method presented in PCT/FI96/00669 the problem is alleviated by sending data frames selectively only on certain subchannels when the maximum transmission capacity allocated for the data connection is not needed. On other subchannels allocated for the connection there is either no transmission at all

or there is subchannel-specific discontinuous transmission. A reduction in the number of active subchannels leads directly to a drop in the power consumption of the transmitter, a decrease in problems of temperature, and to simpler timing of reception, transmission, and measuring of neighbouring cells. In addition, since unnecessary transmissions in the radio interface are reduced, the interference level also drops in the mobile network.

In circuit-switched data transmission services a dedicated circuit-switched connection (e.g. traffic channel of radio interface) is allocated for a data call. The number of simultaneous users is then limited to the maximum number of traffic channels. In packet-mode or packet-switched data transmission service, individual data packets are transmitted on the basis of the addresses or through a virtual connection established. In the radio interface a traffic channel may be allocated to several users (trunking) for packet-mode data transmission, which increases the capacity of the radio network, measured on the number of users. Packet-mode data service is advantageous particularly when data transmission is arbitrary but the connection is to be maintained continuously to enable quick data transmission. Packet-switched data transmission may be implemented in a dedicated packet radio network or as a supplementary service in a normal circuit-switched radio network.

A General Packet Radio Service GPRS that is being developed for the Pan-European mobile system GSM (Global System for Mobile Communication), for example, is a new GSM service, and it is one of the subjects of standardisation in GSM stage 2+ in the ETSI (European Telecommunication Standard Institute). The operational environment of the GPRS comprises one or more subnetwork service areas, which are interconnected by a GPRS Backbone Network. The subnetwork comprises packet data service nodes SN, which are here called serving GPRS support nodes SGSN, and each one of which is connected to the GSM mobile network (typically to base station systems) so that it can offer packet data service to mobile data terminal equipments through several base stations, i.e. cells. The mobile network in between provides packet-mode data transmission between a support node and mobile data terminal equipments. The different subnetworks, in turn, are connected to an external data network, e.g. a packet switched public data network PSPDN, through particular GPRS gateway support nodes GGSN. With the GPRS service, packet data transmission can

thus be effected between mobile data terminal equipments and external data networks, whereby the GSM network operates as an access network. Transceivers and channels of the base station are allocated for circuit-switched calls and packet-mode calls on demand.

DISCLOSURE OF THE INVENTION

The object of the invention it to increase data transmission capacity in radio networks that support both circuit-switched and packet-mode transmission services.

The object is achieved by a radio system comprising mobile stations, a base station network in which each base station supports both circuit-switched calls and packet-mode data transmission, and a discontinuous transmission state that can be activated for a circuit-switched call in the downlink direction. The invention is characterized in that a downlink traffic channel of the base station allocated for an ongoing circuit-switched call in a discontinuous transmission state can be allocated for separate packet-mode data transmission for the duration of the discontinuous transmission state (DTX) of the circuit-switched call.

The invention also relates to a data transmission method for a radio system, comprising mobile stations and a base station network in which each base station supports both circuit-switched calls and packet-mode data transmission, and which comprises a discontinuous transmission state that can be activated for a circuit-switched call at least in the downlink direction, the method comprising the steps of allocating a downlink traffic channel for a circuit-switched call at a base station; establishing a circuit-switched call; transmitting circuit-switched information on said downlink traffic channel from said base station; activating a discontinuous transmission state in said circuit-switched call. The method is characterized by further comprising the steps of

allocating said downlink traffic channel that has been allocated for a circuit-switched call in a discontinuous transmission state also for packet-mode data transmission for the duration of the discontinuous transmission state of the circuit-switched call,

transmitting packet-mode data during said discontinuous transmission state on said downlink traffic channel,

stopping the transmission of packet-mode data on said downlink traffic channel and returning the downlink traffic channel to the circuit-switched call, when said discontinuous transmission state ends.

The invention also relates to transmission equipment of a radio system which supports both circuit-switched calls and packet-mode data transmission and in which a discontinuous transmission state can be activated for a circuit-switched call. The equipment is characterized in that a traffic channel of the transmission equipment with an ongoing circuit-switched call in a discontinuous transmission state can be allocated for separate packet-mode data transmission for the duration of the discontinuous transmission state (DTX) of the circuit-switched call.

In the present invention, any pauses and moments when less transmission capacity is needed in a information stream (voice or data signal) of a circuit-switched call, i.e. when the call is in a discontinuous transmission state (DTX), are used for transmitting packet-mode information from the base station on the same downlink traffic channel. When the circuit-switched call switches to a DTX state (transmission of information is interrupted), data packets of a packet-mode call (calls) are transmitted on the traffic channel allocated for the circuit-switched call, until the discontinuous transmission state ends. A traffic channel may be allocated for packet-mode data transmission (calls) separately in connection with each DTX, but long-term allocation is also possible. Long-term allocation may be advantageous, for example, when at least one other downlink traffic channel is available to the packet-mode call, and when the capacity is added by means of the invention in the downlink direction. For the duration of the DTX states, a traffic channel is allocated for packet-mode transmission typically to mobile stations other than the one to which the traffic channel is allocated for circuit-switched transmission. The transmission capacity can thus be optimally allocated to the network users that need it. The mobile stations may belong to different systems, such as to a packet data radio network and a circuit-switched radio network. The mobile station (mobile stations) for the packet-mode data transmission of which a traffic channel is allocated is controlled to receive on the channel allocated. It receives the data packets addressed to it quite normally, but rejects any information received concerning the circuit-switched call. Correspondingly, the mobile station with the ongoing circuit-switched call receives quite normally in the DTX state but rejects all packet-mode information as being defective. In other words, both (each) mobile stations receive on a traffic channel as if the channel were permanently allocated to the mobile station concerned, so the mobile station need not have any facilities for processing or understanding the

traffic of the other mobile station. In the simplest form the invention can be implemented without making any changes in the terminal equipments, which makes the invention easier to implement in existing networks. Changes are needed only at the base station or in some other network element. A traffic channel may also be allocated to one and the same mobile station for both circuit-switched and packet-mode traffic, but the mobile station then has to be modified particularly for this purpose. Such allocation is also much less effective in respect of the use of network capacity than dynamic allocation of DTX states to a large number of users for packet-mode transmission according to the users' transmission needs. An advantage of packet-mode data transmission is that data of several users can be transmitted during one and the same DTX state, and so the entire capacity offered by the DTX can be used much more effectively.

The method of the invention allows much more effective use of radio network capacity in the downlink direction. A normal voice call can be estimated to be up to 40 to 50% of the time in a DTX state in one direction of transmission (in normal conversation, the participants take turns to speak rather than speak simultaneously). In any case, the voice comprises pauses of several seconds during which thousands of bytes of data (e.g. about 500 bytes/0.5 seconds) can be transmitted. Particularly in the downlink direction, all capacity available is needed, since the majority of the data traffic is transmitted in that direction. Typically, mobile stations order services and information in the uplink direction and receive the data ordered, e.g. a World Wide Web (WWW) page or a file in the downlink direction.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described by means of preferred embodiments with reference to the attached drawings, in which

fig. 1 shows GSM/GPRS system architecture,

figs. 2A, 2B and 2C show alternative locations of a packet control unit PCU,

fig. 3 is a general block diagram of a base station according to the invention,

fig. 4 is a flow diagram illustrating the operation of a channel controller 31 of the base station according to fig. 3,

fig. 5 is a flow diagram illustrating the operation of the PCU/CCU of fig. 3,

fig. 6 is a signalling diagram illustrating the signals of the base station of fig. 3.

PREFERRED EMBODIMENTS OF THE INVENTION

The present invention is suitable for use in different types of radio systems that support both circuit-switched and packet-switched transmission services. Particularly advantageously, the invention is suited for use in the Pan-European digital mobile system GSM (Global System for Mobile Communication) and in other similar mobile systems, such as DCS1800 and the Personal Communication System PCS, in connection with the General Packet Radio Service GPRS. In the following the preferred embodiments of the invention will be described with reference to the GPRS/GSM system, but the invention is not to be understood as being limited to any particular radio system.

Fig. 1 illustrates the basic architecture of the GSM system, and the architecture of a GPRS packet radio network implemented in the GSM system.

The basic structure of the GSM network consists of two parts: a Base Station System BSS and a Network Subsystem NSS. The BBS and mobile stations MS communicate via radio connections. In the base station system BSS each cell is served by a Base Transceiver Station BTS. Base stations are connected to a Base Station Controller BSC, which has the function of controlling the radio frequencies and channels that the BTS uses. The BSCs are connected to a Mobile Switching Centre MSC. With regard to a more detailed description of the GSM system, reference is made to the ETSI/GSM recommendations, and to *The GSM System for Mobile Communications* by M. Mouly and M. Pautet, Palaiseau, France, 1992, ISBN:2-9507190-07-7.

In the GSM system, voice and data transmission are effected entirely digitally on circuit-switched connections. The voice coding method currently used in voice transmission is the RPE-LTP (Regular Pulse Exitation - Long Term Prediction), which utilises both long-term and short-term prediction. The coding produces LAR, RPE and LTP parameters, which are transmitted instead of actual voice. Voice transmission is discussed in chapter 06 of the GSM recommendations, voice coding particularly in recommendation 06.10. In the near future, other coding methods will also be used, e.g. half rate methods, with which the invention can also be used as such. Since the actual invention is not directed to an actual voice coding method, and since the invention is

independent of the method, the method will not be discussed in greater detail herein.

A mobile station must naturally have a voice encoder and decoder for coding of voice. Since it is not essential to the invention how the mobile station is implemented, and since the implementation does not differ from what is usual, the implementation will not be discussed in greater detail herein.

On the network side, different voice coding and rate adaptation functions are centred in a Transcoder/Rate Adaptor Unit TRCU. The TRCU may be arranged in several alternative locations in the system, depending on the choices made by the manufacturer. The interfaces of the transcoder unit are a 64 kbit/s Pulse Code Modulation PCM interface (A-interface) towards the mobile switching centre MSC and a 16 or 8 kbit/s GSM interface towards the base transceiver station BTS. In connection with these interfaces the terms uplink and downlink direction also occur in the GSM recommendations, the uplink direction being the direction from the base transceiver station BTS to the mobile switching centre MSC, and the downlink direction being the opposite direction.

The transcoder unit TRCU is typically positioned in connection with the mobile switching centre MSC, but it can also be part of the base station controller BSC or base transceiver station BTS. When the transcoder unit TRCU is located separately from the base station BTS, information is transferred between the base station BTS and the transcoder unit TRCU in TRAU frames. The TRAU frames are defined in GSM recommendation 08.60 (or 08.61). Depending on the information content, the frame can be a speech frame, use/maintenance frame, or data frame, or an 'idle' speech frame. To effect synchronisation, the first two octets of each frame contain 16 sync bits. In addition, the first bit of the 16-bit words (2 octets) forming a frame is a synchronisation check bit. Apart form the bits containing actual speech, data or use/maintenance information, all frames comprise control bits, in which is transferred information concerning the frame type, and a varying amount of other type-specific information. In addition, for example in a speech or idle frame the last four bits T1-T4 are reserved for the above-mentioned adjustment of timing. A TRAU speech frame comprises 21 control bits C1-C21, in addition to which the last four bits T1-T4 of the frame are reserved for the adjustment of timing. The actual speech-information-transferring bits are located in octets 4-38. In practice, the speech information to be transferred

comprises LAR, RPE and LTP parameters of the RPE-LTP (Regular Pulse Exitation - Long Term Prediction) speech coding method. An idle speech frame is similar to the speech frame of fig. 2, except that all the traffic bits of the frame are in the logical '1' state. Bits C13-C14 form a SID code (Silence Descriptor). Bit C17 is a downlink DTX bit indicating whether discontinuous transmission DTX can be used in the downlink direction (DTX=1) or not (DTX=0). Bit C16 is an SP bit indicating in the downlink direction whether the TRAU frame contains speech (SP=1) or whether the frame is a SID frame (SP=0) containing information about the background noise of the transmission side.

Discontinuous transmission DTX here refers generally to a method by which transmission over the radio path is usually interrupted for the duration of any pauses occurring in the voice transmission (or any other information stream). In the GSM system, downlink DTX is implemented by three major structural components. In the transcoder TRCU is needed Voice Activity Detection VAD, by which it can be checked whether a voice signal contains speech or pure background noise. In a normal transfer state the TRCU sends speech frames (SP=1) to the base station. When speech is no longer detected, the TRCU will start sending SID frames (SP=0) to the base station BTS after the period of time needed for computing the parameters of the background noise. The BTS sends the speech frames directly to the radio path. When the BTS receives a first SID frame, it sends the frame to the radio path and switches to a downlink DTX state. In the DTX the BTS receives SID frames from the transcoder TRCU continuously, but sends them to the radio path only at predetermined intervals (480 ms) to update noise parameters. The DTX continues until the BTS receives a speech frame (SP=1) from the transcoder TRCU, whereby the BTS switches back to continuous transmission.

The primary advantage of downlink DTX is that it reduces interference in a cellular network, and makes discontinuous reception possible in a mobile station. The inventors have realised that during a DTX state a physical traffic channel allocated for a call is unused and the capacity can be allocated for other downlink transmission. In the preferred embodiment of the invention, this other downlink transmission is GPRS packet data transmission.

With further reference to fig. 1, the GPRS system comprises a GPRS network with two serving GPRS support nodes (SGSN) and one GPRS

gateway support node (GGSN). The different support nodes SGSN and GGSN are interconnected by an Intra-Operator Backbone Network 13. It will be understood that the GPRS network may comprise any number of support and gateway nodes. A GPRS gateway support node GGSN connects the operator to the GPRS systems of the other operators of the GPRS network and to data networks 11-12, such as the Inter-Operator Backbone Network, IP Network (Internet), and X.25 network.

The serving GPRS support node SGSN is a node that serves a mobile station MS. Each support node SGSN controls the packet data service in the area of one or more cells in a cellular packet radio network. For this, each support node SGSN is connected (Gb interface) to a certain regional part of the GSM mobile system. The connection is typically to a base station system BSS, i.e. a base station controller BSC (like in fig. 1), or to one of the base stations BTS. A mobile station MS in the cell communicates over a radio interface with a base transceiver station BTS and further through a mobile network with the support node SGSN to the service area of which the cell belongs. In principle, the mobile network between the support node SGSN and the mobile station MS forwards packets only between these two. For this, the mobile network provides a physical connection for the transmission of data packets between the mobile station MS and the serving support node SGSN.

A cell supporting the GPRS can allocate radio resources on one or more physical channels to support GPRS traffic. A physical channel (e.g. time slot) is called a packet data traffic channel PDTCH. It is allocated temporarily to one GPRS_MS or a group of GPRSs. In multiple time slot operation, one GPRS_MS can use several PDTCH channels in parallel (at most eight time slots on one and the same carrier frequency) for its own packet transmission. The physical channels allocated are taken from a pool of channels available in the cell. Physical channels are allocated to circuit-switched GSM services and GPRS services dynamically on the capacity-on-demand principle. The common signalling required by the GPRS is transferred on a packet common control channel PCCCH, if one has been allocated, or on a GSM common control channel.

The GPRS does not require permanently allocated PDTCH channels. Allocation of capacity for the GPRS can be based on the demands of actual packet transmission, which is here called the capacity-on-demand principle. The advantage of dynamic allocation is that the operator can, in a

load situation, allocate unused channels for GPRS traffic to raise the quality of GPRS service. The operator, however, may dedicate some channels for GPRS use permanently or temporarily.

A base station system and an SGSN are connected by a Gb interface, which allows interchange of data and signalling information. The signalling also includes packet channel allocation signalling, e.g. setting up of a virtual connection from the SGSN to a radio resource group located at the base transceiver station BTS. The connection can also be a circuit-switched connection.

More particularly, the Gb interface is defined to be located between the packet control unit PCU and the SGSN. The PCU is an operational unit responsible for different protocols of the GPRS MAC (Medium Access Control) and RLC (Radio Link Control) layers, the protocols being defined in GSM recommendation 03.64. The protocols include, for example, building of RLC blocks for downlink transmission, channel access control functions (access request and access grants), and radio channel management functions, such as power control, allocation and release of radio channels, broadcasting of control information, etc.

The PCU, in turn, is connected to a channel codec unit CCU via an Abis interface. The CCU functions include channel coding functions (including forward error correction FEC, and multiplexing), and radio channel measuring functions. The CCU also forms GPRS blocks, i.e. GPRS packets, in which data and signalling information are transmitted over the radio interface. As shown in figs. 2A-C, the CCU is always located at the base station BTS, but the PCU has many alternative locations: the base station BTS (fig. 2A), base station controller BSC (fig. 2B), or support node SGSN (fig. 2C). When the PCU is located separately from the BTS, the CCU can control some of the functions of the PCU.

The invention can be applied in all the alternative locations of the PCU. The implementation, however, is at its simplest and the most effective with respect to utilisation of the radio path when the PCU is located at the base station. Fig. 3 shows a base transceiver station BTS of the invention, comprising a PCU/CCU unit (PCU and CCU combined), a GSM traffic channel controller 31, and a radio unit 30.

The GSM channel control unit represents, generally, baseband signal processing of a base transceiver station BTS, carried out on a downlink

signal before the transmission: e.g. channel coding, multiplexing, etc. The most important facility with respect to the invention is the controlling of downlink DTX. The channel controller 31 receives downlink GSM traffic on a digital connection (Abis interface) from a base station controller. The GSM traffic comprises TRAU frames, which the channel controller 31 processes and sends in form of radio interface frames to the radio unit 30 through a line 32. The channel controller 31 carries out baseband processing of eight GSM traffic channels. In addition, the channel controller 31 is provided with an additional function according to the invention: it indicates the beginning and termination of a downlink DTX state by a DTX_DETECTED line. Each GSM traffic channel has dedicated DTX_DETECTED line, and dedicated line 32.

The PCU/CCU comprises the combined functions of the PCU and the CCU. The PCU/CCU receives GPRS traffic via a digital connection 35 (Gb interface). The connection 35 can be made through the base station controller BSC or some other route from the support node SGSN. The PCU/CCU is connected through line 33 to the radio unit 30, from which it can allocate traffic channels for GPRS use. For each traffic channel there is a separate line 33. In addition, the PCU is provided with the additional feature according to the invention that it can allocate for GPRS traffic a traffic channel that has been allocated for a circuit-switched GSM call but is currently in a DTX state.

The radio unit 30 represents, generally, radio frequency parts of a radio frequency channel, and baseband signal processing immediately associated with it. Since one radio frequency channel comprises eight time slots (GSM), the capacity of the radio unit 30 is eight traffic channels. These traffic channels can be allocated on demand for GSM traffic or GPRS traffic. In addition, the radio unit 30 is provided with the feature according to the invention that it sends GPRS information obtained from the PCU/CCU on a traffic channel allocated for a circuit-switched GSM call, if the corresponding DTX_DETECTED line has been set.

In the following, we shall study the operation of a base transceiver station BTS according to the invention by means of an example.

Let us first assume that a circuit-switched GSM voice call has been set up according to the normal call set-up procedures of the GSM system, and a traffic channel ch4 has been allocated for the call. The GSM channel control unit 31 receives speech and SID frames according to fig. 6 from line 34, and processes them as required by the GSM. In addition, the channel control unit

carries out a function according to the block diagram of fig. 4 on each channel. At first, in block 41, the control unit 31 checks whether the frame received from line 34 is a SID frame. If it is not a SID frame, the routine proceeds to block 44, in which the continuous transmission state is either maintained or re-established. After this, the DTX_DETECTED line is reset (deactivated). In the example of fig. 6, blocks 44 and 45 are carried out on the first three frames. When the frame received from line 34 is a SID frame in block 31, the channel controller 31 switches to a downlink DTX state in block 41. Upon switching to the DTX state, the channel controller still sends the first SID frame to the radio unit 30. After this the channel controller 31 sets (activates) the DTX_DETECTED line of the traffic channel concerned, as is illustrated in fig. 6.

Until now the radio unit 30 has sent GSM information, i.e. three speech frames and one SID frame, on traffic channel ch4, since the DTX_DETECTED line corresponding to the traffic channel has been reset. When the DTX_DETECTED line is set, the radio unit 30 starts to send GPRS information received from line 33 on traffic channel ch4.

With reference to the flow diagram of fig. 5, when the PCU/CCU detects that the DTX_DETECTED line of the traffic channel has been set (block 51), it starts temporary allocation of the traffic channel as a GPRS traffic channel PDTCH for one or more GPRS_MSs (if more downlink transmission capacity is needed) (block 52). Transmission of packet data to a mobile station MS in a GPRS-Ready state is started by the PCU by sending a Packet Resource Assignment or Reassignment message (block 53) according to the GPRS procedures. If the MS is not in the GPRS-Ready state, signalling according to the GPRS recommendations is first performed to activate the Ready state. Since the aim of the invention is to provide additional capacity, it is very likely that the MS is in the Ready state (or even receiving on one or more other traffic channels). If the cell comprises an allocated PCCCH, the Packet Resource Assignment message is sent on a PAGH. If the cell does not comprise an allocated PCCCH, the Packet Resource Assignment message is sent on an AGCH. The Packet Resource Assignment message comprises a list of packet traffic channel(s) PDTCH (here: channel ch4) used for downlink transmission, and a PDTCH used for carrying uplink PACCH. Timing advance and power control are also involved, if available. Otherwise the MS can be asked to respond by an access burst. After this the PCU/CCU starts to feed

GPRS packet data to the radio unit 30 via line 33 (block 54). The radio unit 30 forwards the GPRS data on the downlink channel ch4 over the radio path, as shown in fig. 6. Multiplexing of radio blocks addressed to different mobile stations MS to one and the same downlink PDTCH is made possible by an identifier contained in each radio block. In data transmission, selective acknowledgement may be used. The PCU may then request (polling) the MS to send a Packet Ack/Nack in the uplink direction.

The PCU/CCU continues to send GPRS data until it is detected block 55) that the DTX_DETECTED line has been reset. In the example (fig. 6) the channel controller 31 switches to a continuous transmission state and reset the DTX_DETECTED line when the channel controller receives the first speech frame in the DTX state. The channel controller 31 restarts forwarding speech frames. Since the DTX_DETECTED line has been reset, the radio unit 30 switches to traffic channel ch4 to send GSM information obtained from the channel controller 31.

When the PCU/CCU has detected in block 55 that the DTX_DETECTED line has been reset, it stops supplying GPRS packet data to the radio unit 30. In addition, the PCU/CCU releases the allocation of traffic channel ch4 as a GPRS traffic channel PDTCH according to the GPRS procedures. The releasing of the resources is started by the PCU by stopping the downlink transmission and requesting the MS for a final acknowledgement. When the downlink transmission on the PDTCH ends, the MS moves to listen to the PCCCH, whereby a new PDTCH can be assigned to it, if necessary, by sending a Packet Resource Assignment message. The PCU may also re-allocate the current downlink PDTCH by sending a Packet Resources Reassignment message, which is acknowledged by the MS. For example, reassignment to another GSM traffic channel in a DTX state is possible.

In a preferred embodiment of the invention, the GPRS allocation lasts only for one DTX state. The GPRS allocation may also last for a longer period of time, i.e. for several DTX states. The Packet Resource Assignment message then needs to be sent only at the beginning of the first DTX, i.e. before the data transmission starts. In the DTX states that follow, data transmission can be started directly without any signalling. Long-term allocation may be advantageous e.g. when additional capacity is offered by the invention for data transmission taking place on one or more other traffic channels. The traffic controller 31 can also reset the DTX_DETECTED line so

as to send a SID frame in a DTX state at predetermined intervals. This may lead to GPRS allocation after each SID updating frame (about 0.5 s). This can be avoided if the PCU/CCU waits for the duration of at least one frame to make sure whether SID updating or starting of a speech transmission was concerned. If is was SID updating, the DTX_DETECTED line will be reset and the PCU/CCU can continue the transmission with the same allocation.

A GSM_MS can receive GPRS data, but it rejects the data as defective. A GPRS_MS may also receive GSM speech and SID frames, but again it rejects them as defective. The invention should thus not require any changes in terminal equipments .

In an embodiment of the invention the channel controller 31 and the PCU/CCU are connected to the radio unit 30 by means of a common time division multiplexed bus. On the bus, one time slot corresponds to one traffic channel. The radio unit 30 reads the content of the time slot from the bus, and forwards it on the traffic channel concerned. When the channel controller 31 writes onto the bus in a continuous transmission state, and the PCU/CCU in a DTX state, no collisions occur. In the embodiment, the DTX_DETECTED line need not be connected to the radio unit 30.

The invention has been described above by means of an example in which a voice codec and VAD and DTX functions are arranged in a transcoder unit separate from the base station BTS. The voice codec and DTX functions can naturally also be arranged at the base station, whereby information about the DTX state can be obtained directly without identification of SID frames. Even otherwise the invention can be applied in any type of base station whatsoever and in any other transmission equipment for sending packet-mode information during the DTX states of a circuit-switched call.

The invention has been described above with reference to voice calls, but it can also be applied in connection with DTX of data calls. For example in the multichannel transmission disclosed in PCT/FI95/00669, on some of the channels allocated there is not necessarily any kind of transmission, or there is subchannel-specific discontinuous transmission. In the present invention, such 'inefficiently utilised' traffic channels can serve as additional capacity for GPRS data transmission.

The figures and the associated specification are to be understood only as illustrating the invention. The invention may vary in its details within the scope and spirit of the attached claims.

CLAIMS

1. A radio system comprising
mobile stations (MS),
a base station network in which each base station (BTS) supports both circuit-switched calls and packet-mode data transmission, and
a discontinuous transmission state that can be activated for a circuit-switched call in the downlink direction,
characterized in that
a downlink traffic channel of the base station allocated for an ongoing circuit-switched call in a discontinuous transmission state can be allocated for separate packet-mode data transmission for the duration of the discontinuous transmission state (DTX) of the circuit-switched call.

2. A radio system according to claim 1, **characterized** by comprising a unit (PCU) for allocating radio resources for packet-mode data transmission, the unit being arranged to allocate downlink traffic channels of circuit-switched calls currently in a DTX state for packet-mode data transmission, if additional capacity is needed for packet-mode data transmission in the downlink direction.

3. A radio system according to claim 1 or 2, **characterized** in that the circuit-switched call is a voice call, and that the system comprises a voice transcoder (TRCU) located remote from the base transceiver station (BTS), the voice transcoder sending the base station (BTS) speech parameter frames or noise parameter frames, depending on whether there is speech or not, and that the base station (BTS) is arranged to start a downlink DTX state on a downlink traffic channel and to activate a DTX detected signal in response to reception of a noise parameter frame, and that the base station is arranged to terminate the downlink DTX state on the downlink traffic channel and to deactivate the DTX detected signal in response to reception of a speech frame in the DTX state, and that the radio system further comprises a unit (PCU) for allocating radio resources for packet-mode data transmission, the unit, in response to the activated DTX detected signal, allocating a downlink traffic channel for packet-mode data transmission at least for the duration of the DTX state.

4. A radio system according to claim 1, 2 or 3, **characterized** in that the packet-mode data transmission is packet data transmission according to the GPRS system.

5. A radio system according to claim 4, **characterized** in that said radio resource allocation unit comprises a packet control unit (PCU) of the GPRS system.

6. A radio system according to claim 1, 2, 3, 4 or 5, **characterized** in that the circuit-switched call is a call of the GSM mobile system.

7. A data transmission method for a radio system, comprising mobile stations (MS) and a base station network in which each base transceiver station (BTS) supports both circuit-switched calls and packet-mode data transmission, and which comprises a discontinuous transmission state that can be activated for a circuit-switched call at least in the downlink direction, the method comprising the steps of

allocating a downlink traffic channel for a circuit-switched call at a base station (BTS);

establishing a circuit-switched call;

transmitting circuit-switched information on said downlink traffic channel from said base station (BTS);

activating a discontinuous transmission state in said circuit-switched call,

characterized by further comprising the steps of

allocating said downlink traffic channel that has been allocated for a circuit-switched call in a discontinuous transmission state also for packet-mode data transmission for the duration of the discontinuous transmission state of the circuit-switched call;

transmitting packet-mode data during said discontinuous transmission state on said downlink traffic channel,

stopping the transmission of packet-mode data on said downlink traffic channel and returning the downlink traffic channel to the circuit-switched call, when said discontinuous transmission state ends.

8. A method according to claim 7, **characterized** by

allocating a downlink traffic channel for packet-mode data transmission separately during each discontinuous transmission state,

signalling the allocation to a packet data terminal equipment separately at the beginning of each discontinuous transmission state before starting the transmission of packet-mode data.

9. A method according to claim 7, **characterized** by

allocating a downlink traffic channel for packet-mode data transmission for the duration of several discontinuous transmission states,

signalling the allocation to a packet data terminal equipment at the beginning of the first discontinuous transmission state before starting the transmission of packet-mode data,

interrupting the packet-mode data transmission on the traffic channel and returning the traffic channel to the circuit-switched call at the beginning of a continuous transmission state,

restarting the packet-mode data transmission immediately at the beginning of each of the following discontinuous transmission states.

10. A method according to claim 7, 8 or 9, **characterized** in that the circuit-switched call is a voice call, and that the method comprises the steps of

sending the base station (BTS) speech parameter frames or noise parameter frames, depending on whether there is speech or not, from a voice transcoder (TRCU) located remote from the base station (BTS),

starting a downlink DTX state on a downlink traffic channel at the base station (BTS), and activating a DTX detected signal when a noise parameter frame is received,

terminating the downlink DTX state on the downlink traffic channel and deactivating the DTX detected signal, when a speech frame is received in the DTX state at the base station, and

allocating a downlink traffic channel for packet-mode data transmission at least for the duration of the DTX state by the unit allocating radio resources for packet-mode data transmission, which allocation is separate from allocation of radio resources for circuit-switched calls; indicating a discontinuous transmission state in the stream of information of a circuit-switched call on the traffic channel,

allocating a downlink traffic channel for packet-mode data transmission for the time-being,

indicating any pauses in the transmission of a circuit-switched call,

transmitting information of a packet-mode call during said pauses in the transmission.

11. A method according to any one of claims 7 to 10, **characterized** in that the packet-mode data transmission is data transmission of the GPRS system.

12. A method according to claim 11, **characterized** by allocating a traffic channel for packet-mode data transmission; and signalling the allocation to a packet data terminal equipment in accordance with the procedures of the GPRS system.

13. A method according to any one of claims 7 to 12, **characterized** in that a circuit-switched call is established and discontinuous transmission performed in accordance with the procedures of the GSM system.

14. Transmission equipment of a radio system which supports both circuit-switched calls and packet-mode data transmission and in which a discontinuous transmission state can be activated for a circuit-switched call,

characterized in that

a traffic channel of the transmission equipment (BTS) with an ongoing circuit-switched call in a discontinuous transmission state can be allocated for separate packet-mode data transmission for the duration of the discontinuous transmission state (DTX) of the circuit-switched call.

15. Transmission equipment according to claim 14, **characterized** in that the transmission equipment is a base station (BTS), and that discontinuous transmission can be activated for a downlink traffic channel.

16. Transmission equipment according to claim 15, **characterized** in that the base station (BTS) comprises a unit (PCU/CCU) for allocating radio resources for packet-mode data transmission, the unit being arranged to allocate downlink traffic channels of circuit-switched calls in a DTX state for packet-mode data transmission, if additional capacity is needed for the packet-mode data transmission in the downlink direction.

17. A transmission equipment according to claim 15 or 16, **characterized** in that a circuit-switched call is a voice call, and that a base station (BTS) is arranged to receive speech parameter frames or noise parameter frames from a voice transcoder (TRCU) remote from the base station, the voice transcoder sending the base station (BTS) speech parameter frames or noise parameter frames depending on whether there is speech or not, and that the base station is arranged to start a downlink DTX state on a downlink traffic channel and to activate a DTX detected signal in response to reception of a noise parameter frame, and that the base station (BTS) is arranged to terminate the downlink DTX state on the downlink channel and deactivate the DTX detected signal in response to reception of a

Fig. 1

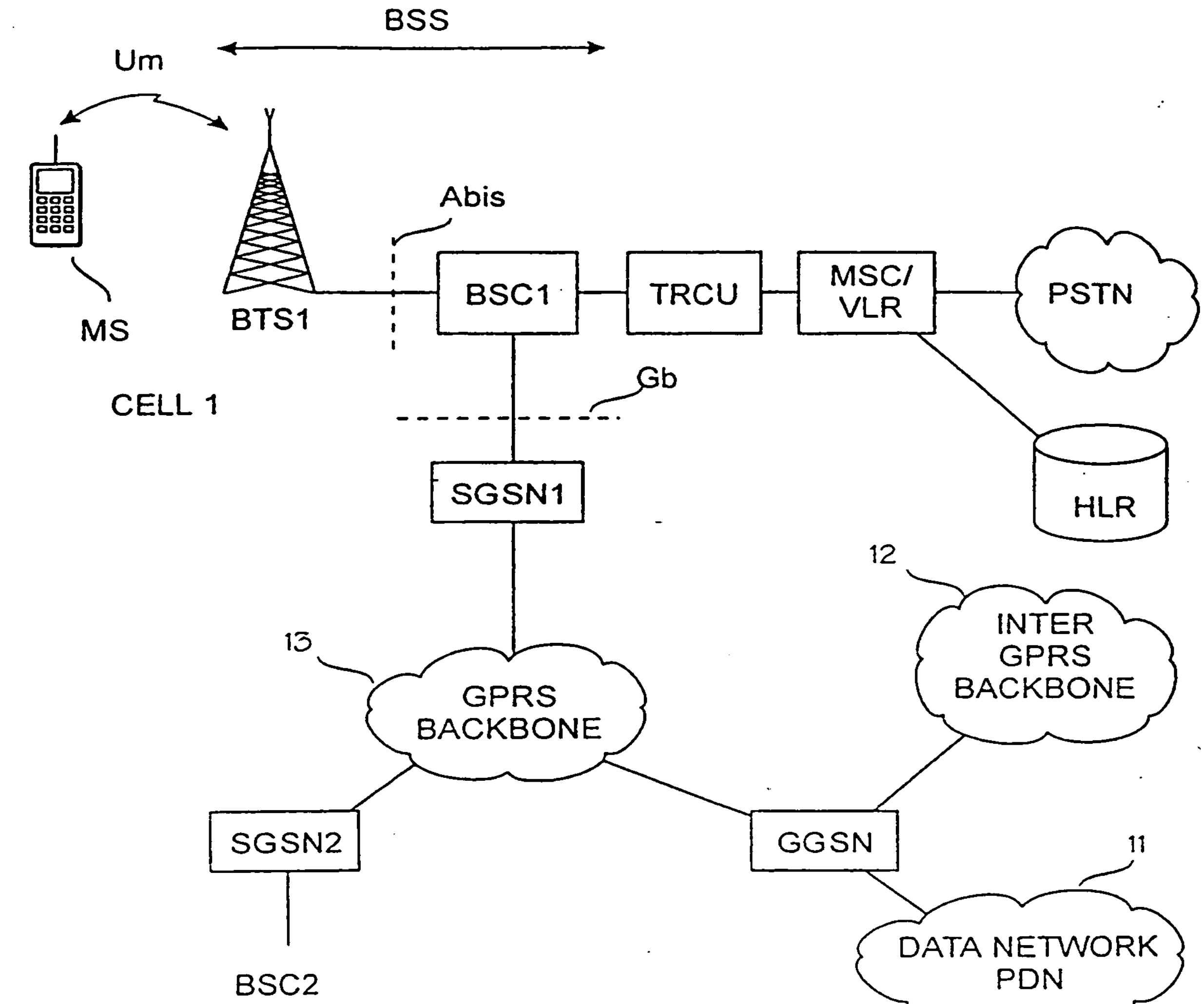
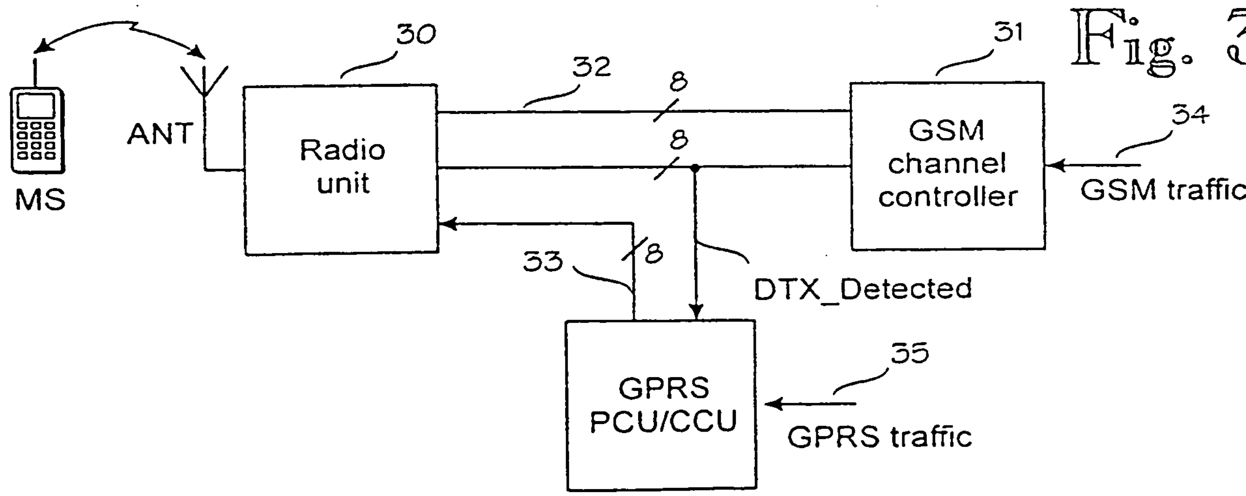

BSS
Um
MS
BTS1
Abis
BSC1
TRCU
MSC/
VLR
PSTN
HLR
Gb
CELL 1
SGSN1
12
INTER
GPRS
BACKBONE
13
GPRS
BACKBONE
SGSN2
GGSN
11
BSC2
DATA NETWORK
PDN

Fig. 3


30
31
32
8
8
MS
ANT
Radio
unit
GSM
channel
controller
34
GSM traffic
33
8
DTX_Detected
35
GPRS
PCU/CCU
GPRS traffic

THIS PAGE BLANK (USPTO)

Fig. 2A

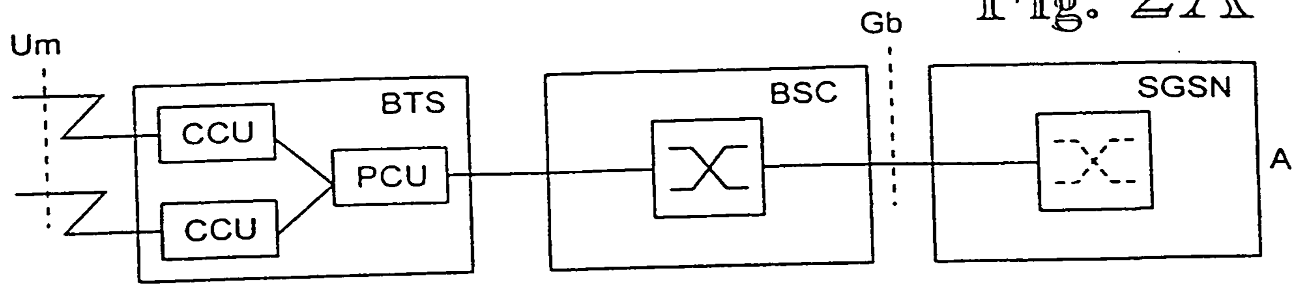


Fig. 2B

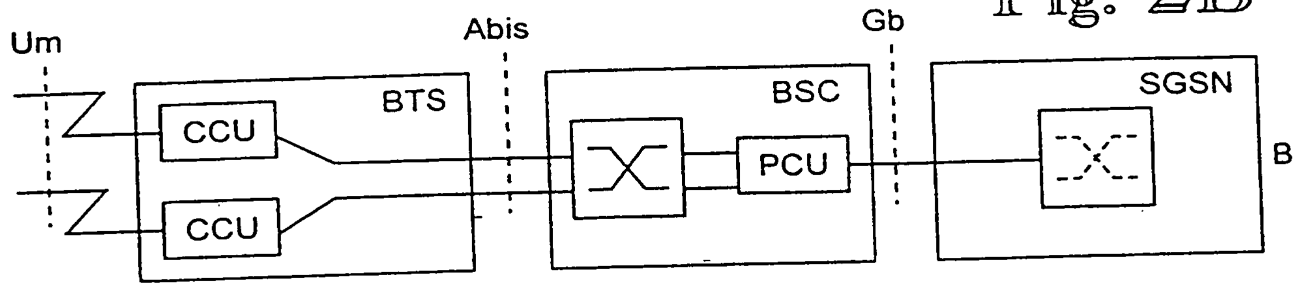
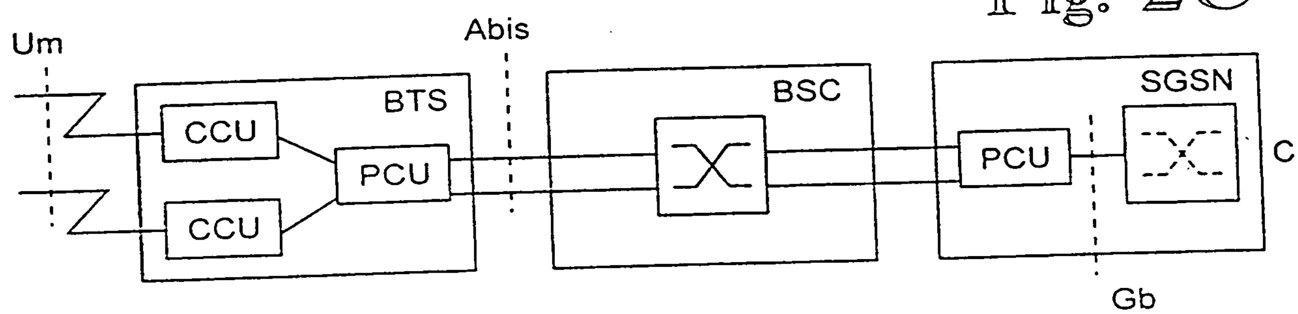


Fig. 2C



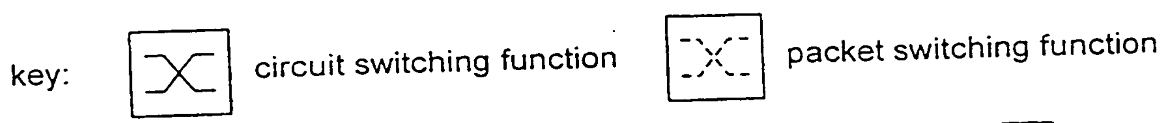


Fig. 4

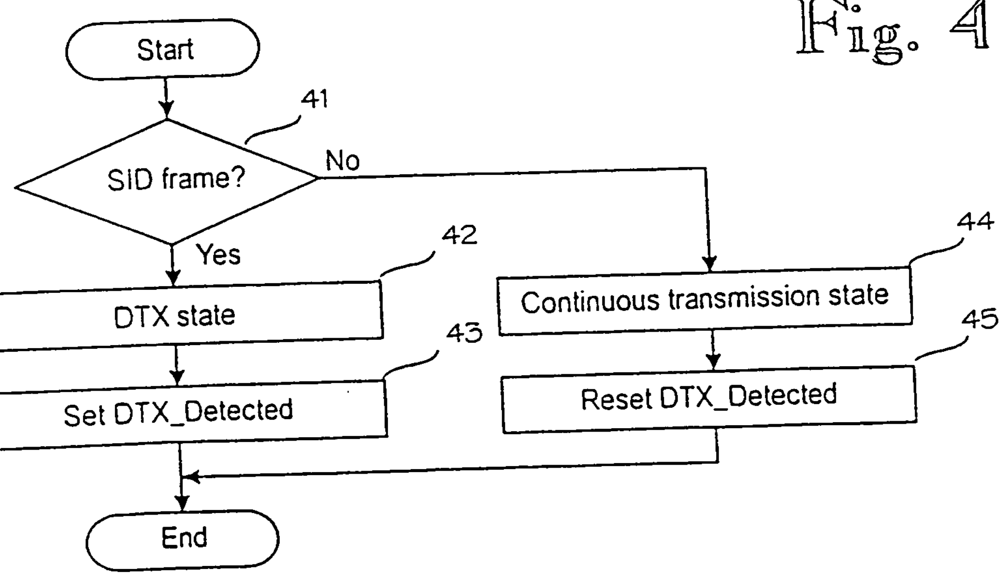


Fig. 5

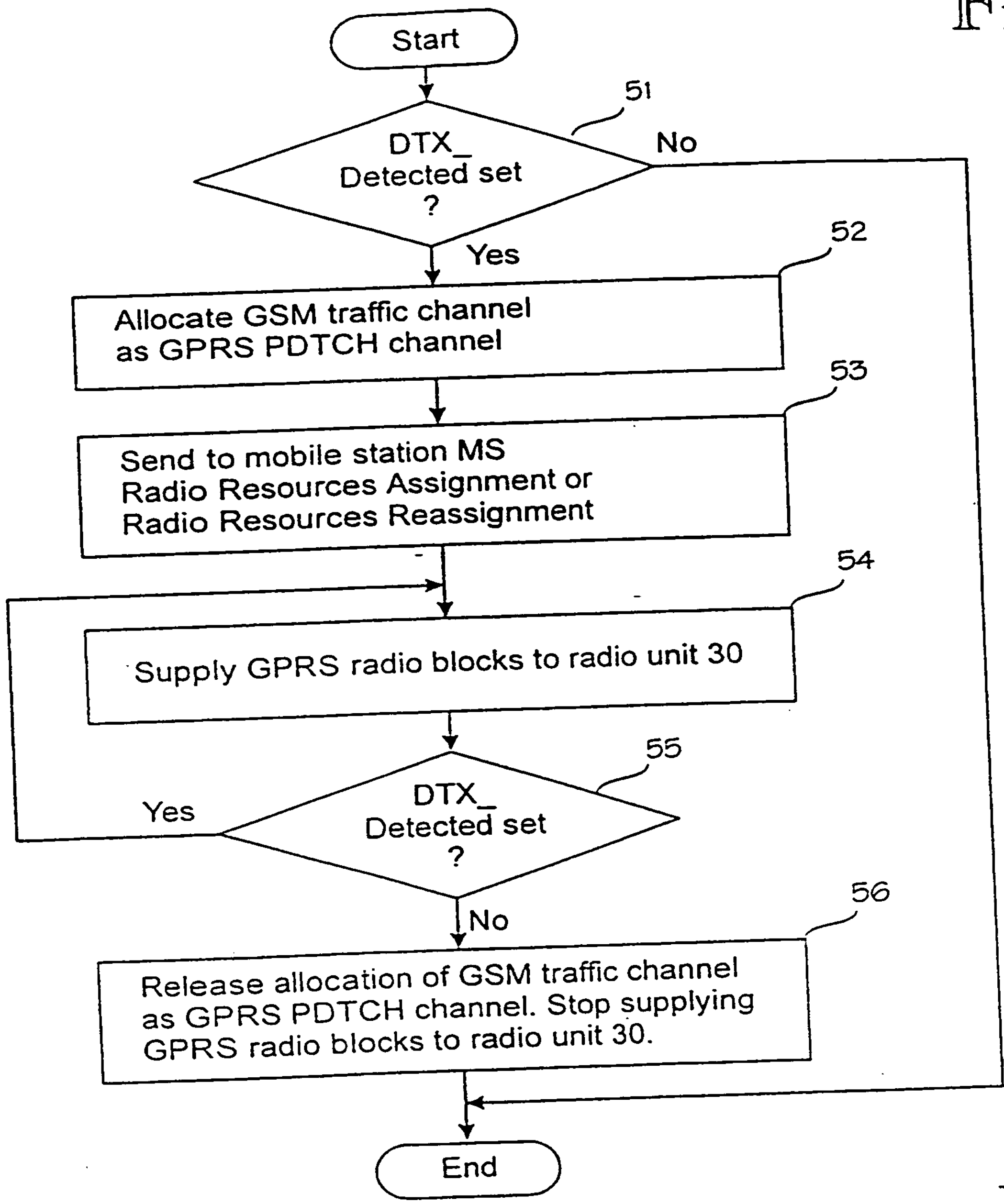
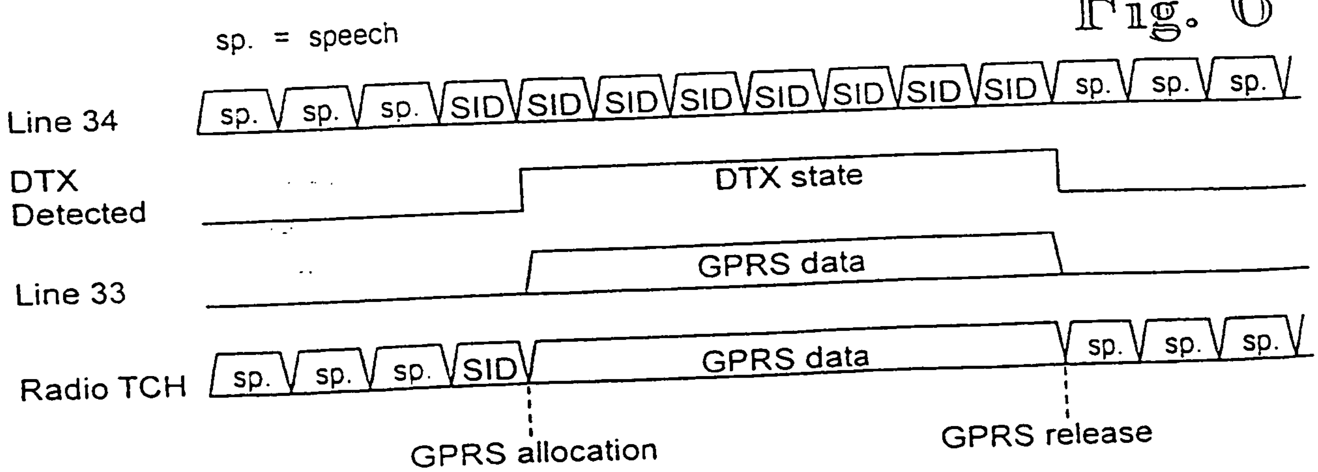

Start
51
DTX_ Detected set ?
No
Yes
52
Allocate GSM traffic channel as GPRS PDTCH channel
53
Send to mobile station MS Radio Resources Assignment or Radio Resources Reassignment
54
Supply GPRS radio blocks to radio unit 30
55
DTX_ Detected set ?
Yes
No
56
Release allocation of GSM traffic channel as GPRS PDTCH channel. Stop supplying GPRS radio blocks to radio unit 30.
End

Fig. 6


sp. = speech
Line 34
sp. sp. sp. SID SID SID SID SID SID SID SID sp. sp. sp.
DTX Detected
DTX state
Line 33
GPRS data
Radio TCH
sp. sp. sp. SID GPRS data sp. sp. sp.
GPRS allocation
GPRS release